# Ships of Opportunity

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**Project Summary**

Ships of Opportunity, also known as Volunteer Observing Ships or VOS, are merchant marine ships that make repeated ocean passages. We focus on fast container ships that make regular crossings of broad areas of the ocean basins and, if possible, those that pass close to our Ocean Reference Stations (ORS), which are surface moorings at fixed locations. This provides broad spatial sampling of the regimes found across ocean basins that is an excellent complement to the high time resolution sampling at our fixed time series sites (ORS). We also select ships that are used by other groups for deployment of XBTs (expendable bathythermographs) and profiling floats, as sharing of logistic support facilitates the work. Our goal is to obtain from the selected VOS time series of surface meteorology and ships velocity and position that are complete and accurate and thus allow us to compute using the bulk formulae time series of air-sea heat (sensible, latent, shortwave, longwave, and net), freshwater, and momentum flux. These time series are used to quantify the spatial variability in the in-situ surface meteorology and air-sea fluxes, to identify spatial biases and other others in gridded meteorological and flux products (such as those from the National Centers for Environmental Prediction (NCEP) or those developed from remote sensing methods), to develop improved fields of air-sea fluxes over the oceans, and to support climate research.

The instrumentation used on the VOS is the Air-Sea Interaction Meteorology (ASIMET) system developed at WHOI. It consists of a central data logger and sensor modules that communicate with the central logger via RS-485. It has been developed to collect one minute averaged values of wind speed and direction, air and sea surface temperature, relative humidity, barometric pressure, incoming shortwave radiation, incoming longwave radiation, and precipitation. It provides hourly averaged data for telemetry in near real time in addition to storing the one-minute data. The ASIMET hardware used in this project is also used on the surface buoys in the Ocean References Stations project. The ASIMET system produces high quality data, accurate enough to support calculation of monthly air-sea heat exchanges to better than 10 W $m^{-2}$. The accurate data from the VOS are used to: 1) identify errors in existing climatological, model-based, and remotely-sensed surface meteorological and air-sea flux fields, 2) to provide the motivation for improvements to existing parameterizations and algorithms used in models and in preparing products from satellite data, 3) to provide the data needed to correct existing climatologies, 4) and to validate new model codes and remote sensing methods. The VOS data, due to the cross-basin, repeat sampling are an important resource for work to improve the accuracy of global fields of the air-sea fluxes of heat, freshwater, and momentum and to document variability and change in the coupling of the atmosphere and the ocean.

The VOS provide a challenging operating environment in which to make high quality surface meteorological observations. Acceleration and vibration, radio frequency interference, freezing temperatures, and power surges are among the issues we have faced. Examination of failure rates of individual ASIMET sensor modules revealed

where the present set of modules introduce reliability problems and negatively impact data return rates and flagged problems with anemometer performance. Examination of success at repeated pre- and post-deployment calibration, and efforts to get close agreement (to roughly 2 W $m^{-2}$) in calibrated sensor modules has identified the incoming longwave radiation module as introducing the largest uncertainty in our heat flux estimates. In response we last year began efforts to improve the performance of these key sensors. We also last year increased work to analyze the surface meteorological and air-sea data collected in the past and on an ongoing basis and to meet the goals for utilization of VOS data. A subcontract to colleagues at the National Oceanographic Centre (NOC, formerly Southampton Oceanography Centre) in the U.K. has addressed another aspect of the challenge of working from VOS, that of flow distortion by the structure of the ship and its cargo.

The Ships of Opportunity Program is managed as three tasks: A) VOS Field Operations, B) Instrumentation Upgrades, and C) Data Processing.

**Accomplishments**

VOS Field Operations

The implementation of the ASIMET hardware on the VOS is the AutoIMET. AutoIMET was developed at WHOI to meet the need for improved marine weather and climate forecasting. It is a wireless, high time resolution system for making systematic, climate quality measurements of surface meteorology. The AutoIMET system interfaces to the NOAA SEAS 2000 (Shipboard Environmental (Data) Acquisition System) that automatically receives the meteorological data and sends in hourly reports via Inmarsat C.

The basic deliverable is the data, supported by the appropriate metadata. Descriptions, technical information and raw data from the several VOS being serviced is posted on our VOS website: http://kuvasz.whoi.edu/vos. Data (plots) are presented for all ship sets. Quality controlled data files are available for the VOS Enterprise for April 2002 through May 2006. Data from other cruises are available by request from Frank Bahr (fbahr@whoi.edu). Instrument design questions can be addressed to Dave Hosom (dhosom@whoi.edu). Data from transects of the Atlantic ship Merkur passing near the NTAS buoy have been processed and used in evaluation of spatial variability. In an effort to obtain quality meteorological data in closer proximity to the NTAS site, we have also begun processing of shipboard data from the NTAS-1 through 6 mooring service cruises.

We have typically supported ASIMET installations on two ships. A first-order challenge is the short lifetime of a given ship on a given route. Our longest running vessel has been the Horizon Enterprise, doing the Oakland -Hawaii-Guam-Taiwan-Tacoma run (Fig. 1). The second VOS was an Atlantic ship (originally the SeaLand Express and then the Merkur during 2004-2005). In February 2006, the Atlantic ship was sold. We are waiting for colleagues at AOML to initiate a new Atlantic ship for XBT sampling and plan to re-install the ASIMET hardware on that ship. At present we are maintaining two Pacific installations, the Horizon Enterprise and the Horizon Hawk. The Enterprise stopped going all the way across the Pacific, and now runs between the West Coast and Hawaii (Fig. 2). A new installation on the Horizon Hawk is evaluating this ship as an alternated trans-Pacific installation, as the Horizon Hawk runs from the west coast to Hawaii, Guam, Taiwan, Hong Kong, and back to the west coast (Fig. 2). The Field

Operations effort carries out two turnarounds per year for each ship that we have systems installed on. This includes the preparation and calibration of the systems, and recovery of the raw data as well as the ancillary time series of ships' position and velocity.

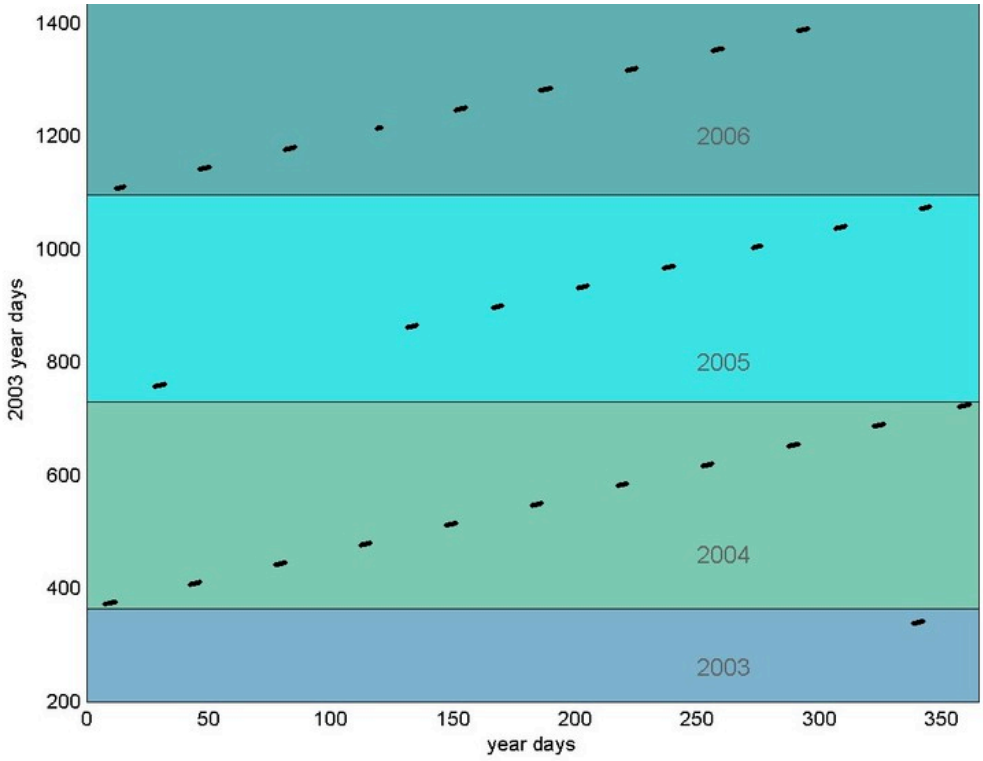
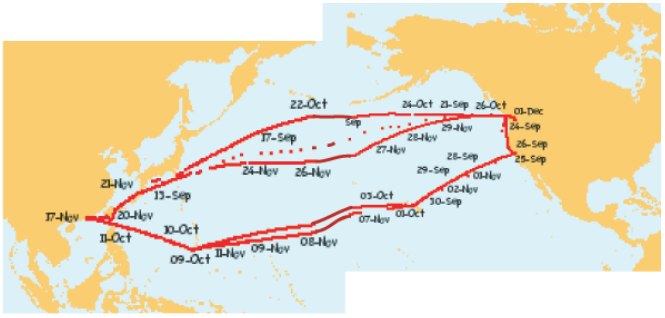



Figure 1. Season vs. year breakdown of twenty nine VOS Horizon Enterprise transects between Oakland CA and Honolulu for the period 2003 – 2006. These data were used to evaluate spatial variability in the ECMWF fields.

Ship selection in the Atlantic and our interface to the NOAA SEAS system is via AOML (Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida). In the Pacific there is ongoing cooperation with Scripps Institution of Oceanography via the CORC (Consortium for Ocean Climate Research) program on Pacific ship scheduling and support. Some logistical support is provided by the Southern California Marine Institute on ship turnarounds. There is also ongoing cooperation with many sensor manufacturers and the VOS people at the German Weather Service (Deutsch Wetter Dienst) in Hamburg Germany.

Horizon Enterprise



Horizon Hawk

Figure 2. Recent routes for the Horizon Enterprise (left) and Horizon Hawk (right).

Specific activities relating to supporting the VOS Horizon Enterprise and Horizon Hawk during the reporting period are listed below.

**May 2006**; Tacoma, WA: Horizon Enterprise. AutoIMET sensor turn-around.
**Nov 2006**; Tacoma, WA: Horizon Enterprise. AutoIMET sensor turn-around.
**Apr 2007**; Oakland, CA: Horizon Enterprise. AutoIMET sensor turn-around.
**Jun 2007**; Honolulu, HI: Horizon Enterprise. Address problem with air temperature (AT) and humidity (HRH) readings.
**Jul 2007**; Oakland, CA: Horizon Hawk. Inspection of vessel in preparation for AutoIMET installation.

For now, the availability of two systems while we await selection of a new Atlantic ship, together with the proven performance of the Horizon Enterprise, has argued for continuing on the Enterprise, even though she only goes from the west coast to Hawaii and back. The push this year has been to instrument the Horizon Hawk to evaluate the possibility of focusing on this ship (rather than the Enterprise) to maintain a trans-Pacific route. We have found that power supplied from the ship as well as the vibration and accelerations need to be addressed. We are doing so and having success. We continue to need to upgrade the hardware to address lessons learned, and we also continue to focus on analysis of the data we have collected. This approach will strengthen the effort by improving data return and by proving the utility of the data by using it in conjunction with data from the Ocean Reference Stations to improve our understanding of the surface meteorological and air-se flux fields.

Instrumentation Upgrades

The VOS provide a challenging operating environment in which to make high quality surface meteorological observations and we have moved to upgrade some sensor modules to address problems. At the same time, we have found that some of the components in our ASIMET circuit boards are no longer available or soon to be obsolete, including the digital memory cards used to log the data. In particular, we have found our highest failure rates are associated with mechanical failures in the propeller/vane anemometer sensor and abrupt loss of data in the ASIMET relative humidity modules. A final problem has been calibration stability in the incoming longwave radiation modules. Work under this task has produced a low-power sonic anemometer sensor that is under test now as a replacement for the current mechanical propeller/vane sensor. A Kipp and Zonen longwave sensor has been used to replace the Eppley longwave sensor and a new front end (preamplifer for the thermopile voltage from the longwave sensor) circuit board has been developed to be used in an upgraded longwave module. Upgrades are being made to the ASIMET electronics. The present flash memory (which is getting hard to obtain and is difficult to use) is being replaced by digital flash memory. Obsolete parts and cold sensitivities are being identified in conjunction with design of a new processor board. Prototype new sensor modules were built and tested at WHOI and in the field.

Data Analysis

Work under this task is yielding information about the spatial variability and coherence of the surface meteorological fields by examining data from VOS track lines. Initial effort in the Atlantic was focused on tracks from the R/V Merkur that passed within 500 km of the NTAS Ocean Reference Station (Fig. 3). Auto-correlation functions for ship and buoy showed that typical de-correlation times are from 3 to 6 h (Fig. 4). Cross-correlation between ship and buoy indicated that spatial correlation scales are < 200 km on short (< 20 h) time scales. Barometric pressure, dominated by the semidiurnal atmospheric tide, and shortwave radiation, dominated by the diurnal cycle, showed the most coherence between ship and buoy.

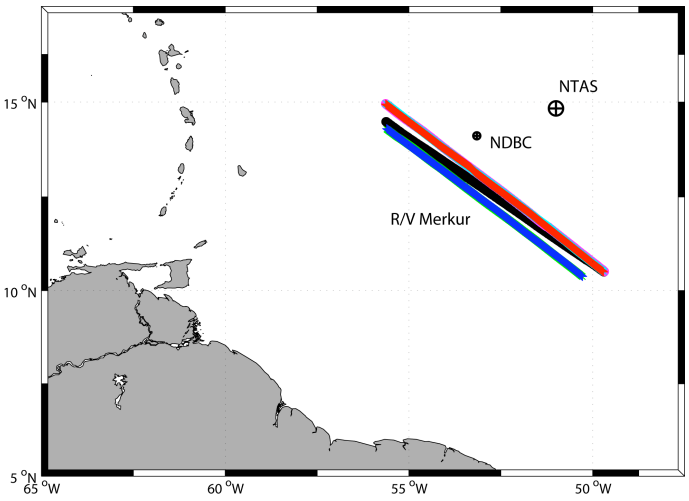



Figure 3. Ship tracks (color) for six "encounters" of the R/V Merkur passing within 50 km of the NTAS buoy. The NDBC 41041 station is also shown.

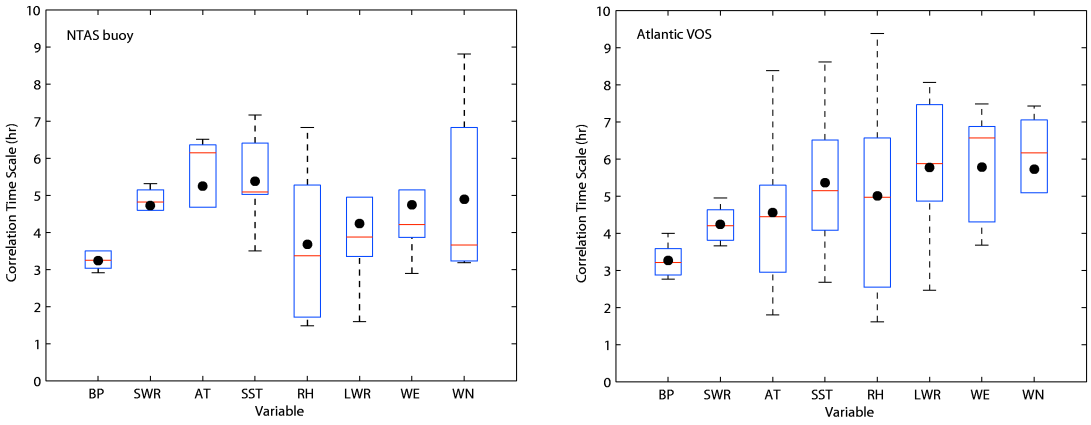



Figure 4. Auto-correlation time scale (hours) for meteorological variables observed on the NTAS buoy (left) and the Atlantic VOS (right). Box plots show the mean (dots), median (red line), upper and lower quartile values (blue box) and extent of data within 1.5 times the inter-quartile range (dashed whiskers).

The second investigation used repeat transects of the Enterprise between Oakland and Honolulu between 2003 and 2006 (Fig. 1). In this study, we compared spatial variability in the VOS records with that of the ECMWF model output along the ship track (Fig. 5). VOS data were averaged to 1 hr and compared with ECMWF data for the

appropriate grid cell during each ~6 day transit. Most variables showed good agreement in the mean, but notable discrepancies were found on short spatial scales.

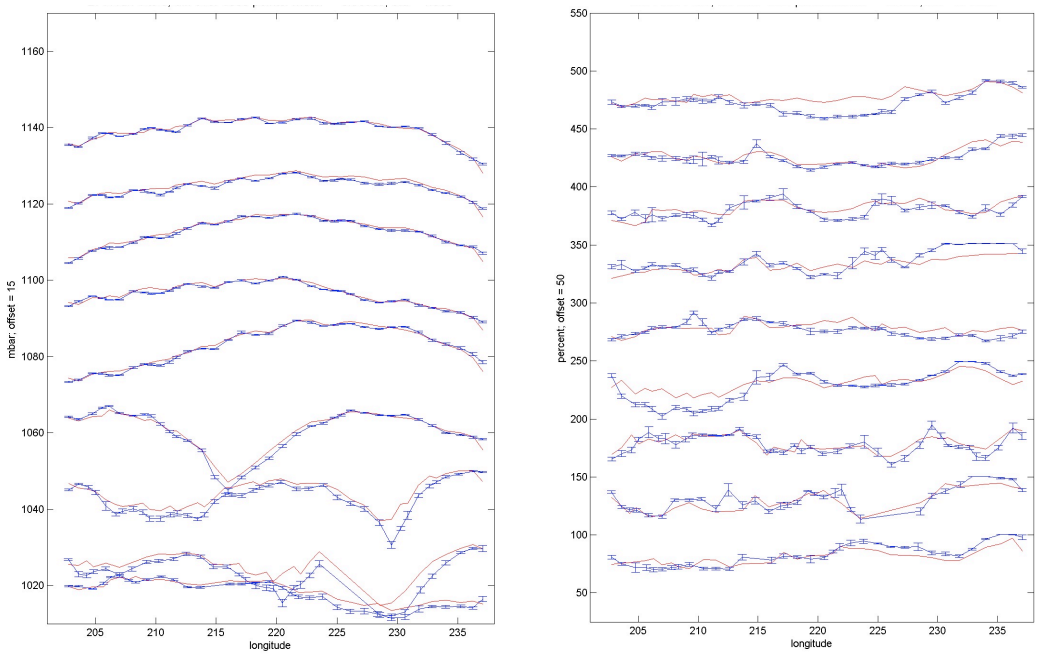



Figure 5. Comparison of hourly averaged BP (left) and RH (right) from the Enterprise VOS (blue, with error bars) and ECMWF (red) for a subset of Oakland-Honolulu transits. Each transit spans about 6 days in time, and is plotted vs. longitude. The first transit of the group is shown at the bottom; an offset has been applied for successive records.

## Publications and Reports

Plueddemann, A., F. Bahr, D. Hosom and R. Weller, 2007. Spatial Variability in Surface Meteorology from a VOS and the ECMWF model, NOAA Office of Climate Observation Annual System Review, Silver Spring, MD (poster).

Plueddemann, A., F. Bahr, D. Hosom and R. Weller, 2006. Surface meteorology from volunteer observing ships, First Joint GOSUD/SAMOS Workshop, 2-4 May, Boulder, CO (poster).

Plueddemann, A., F. Bahr, D. Hosom and R. Weller, 2006. Surface meteorology from volunteer observing ships, NOAA Office of Climate Observation Annual System Review, Silver Spring, MD (poster).

Observations of Air-Sea Fluxes and the Surface of the Ocean. Report for Sub-contract Agreement A100239 between WHOI and the University of Southampton, Southampton Oceanography Centre.